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An Experimental Investigation on Mechanical Properties of Steel Fiber Reinforced Concrete with Mineral Admixtures

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ABSTRACT

Concrete is mainly containing natural sand and gravel or crushed- rock aggregate and water, when placed in the skeleton of form and allowed to cure, becomes hard like stone. High strength concrete is concrete with a compressive strength higher than 40mpa. It is made by lowering the water-cement (W/C) ratio 0.40 or lesser. The admixtures like Ground Granulated Blast furnace Slag (GGBS), silica fume, Rice husk ash, Fly ash, High Reactive Met kaolin etc., are very important ingredients to make high strength concrete.

In this study, Cement was partially substituted by Fly Ash and silica fume. A mix design was done for M40 grade of concrete by using IS method. The utilization of fly-ash and silica fume in concrete as partial substitutement of cement. In this project 53 grade of cement is used. This paper reports comparative study on effects of concrete properties by partially substitutement of OPC of 53 grade with fly ash and silica fume. We have to use the water falling admixture i.e. super plasticizer, which plays an important role for the production of high strength concrete. We have used steel fiber in different percentage i.e. 0.5%, 1%, 1.5% to that of total weight of cementitious material and casting was done. Lastly we used different percentages of silica fume and flay ash with the substitutement of cement keeping constant fiber content and concrete was casted. We prepared concrete cubes, cylinders and beams. Lastly compressive test, splitting test and flexural test are conducted.

Keywords: Steel fiber reinforced concrete. Cement, aggregate, Silica fume, Flyash .

INTRODUCTION

Fiber reinforced concrete (FRC) is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, thousands of little fibers are dispersed and distributed at random in the concrete during mixing, and thus get better concrete properties in all directions. FRC is cement- based compound material that has been developed in recent years. It is a successful way to raise toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar. The fiber is often described by a convenient parameter called ―aspect ratio. The aspect ratio of the fiber is the ratio of its span to its diameter. The principle reason for incorporating fibers into a cement matrix is to raise the toughness and tensile strength and improve the cracking deformation characteristics of the resultant compound. For FRC to be a viable construction material, it must be able to complete cheaply with existing reinforced system.

In plain concrete and similar brittle materials, structural cracks (micro cracks) develop even before loading, mainly due to drying shrinkage or other causes of volume change. The breadth of these original cracks rarely exceeds little microns, but their other two sizes may be of superior magnitude. When loaded the micro cracks propagated and open up, and owing to the effect of the stress concentration, additional cracks form in the places of minor defects. The structural cracks proceed slowly or by tiny jumps because they are retarders by various obstacles. The development of such micro cracks is the main cause of in elastic deformations in concrete.

It has been recognized that the additional of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties .this type of concrete is known as fiber reinforced concrete.FRC is gaining concentration as an effective way to improve the performance of concrete .The fibers are added to fresh concrete during the batching and mixing process to allow them to be equally distributed throughout the concrete.

Presently, steel fibers are the majority commonly researched fiber type concrete. Today, steel fiber reinforced concrete has been used at an increasing rate in various applications like: mine and tunnel linings, slabs and floors (especially those large slabs of factories on which there are great moving loads), rock slope stabilization, repair mortars, shell domes, refractory linings, dam constructions, composite metal decks, aqueduct rehabilitations, seismic retrofitting, repairs and rehabilitations of marine structures, fire protection coatings, concrete pipes and even conventional reinforced concrete frames because of improved toughness against dynamic loads.

Although a lot of researches have been carried out on the properties of steel fiber reinforced high strength concrete beams, the results , volume dosage of steel fiber and the beam height on ultimate flexural behavior of steel fiber reinforced high-strength concrete beams are not completely appropriate for practical purposes. Therefore, the present study investigate the ultimate load, ultimate deflection ,crack load, volume dosage of steel fiber and the beam strength on flexural behavior of steel fiber reinforced high-strength concrete beams, which has great instruction in the design and applications of steel fiber reinforced high-strength concrete beams.

STEEL FIBER REINFORCED CONCRETE

Material technology has pointed out the adding of steel fibers in concrete to improve the main characteristics of concrete, such as, stiffness, toughness and ductility. Currently, steel fibers are the mainly commonly researched fiber type concrete. In the 1910s steel elements such as nails and metal chips, were measured as possible sources of reinforcement in concrete. Through both research and experimental work, steel fibers were finally introduced as an effective concrete reinforcement in the 1960s. Today, steel fiber reinforced concrete has been used at an increasing rate in various applications like: mine and channel linings, slabs and floors (especially those large slabs of factories on which there are great moving loads), rock slope stabilization, repair mortars, shell domes, refractory linings, dam constructions, composite metal decks, aqueduct rehabilitations, seismic retrofitting, repairs and rehabilitations of marine structures, fire protection coatings, concrete pipes and even conventional reinforced concrete frames because of improved toughness against dynamic loads. The use of Steel Fiber Reinforced Concrete (SFRC) has received much attention in concrete industry as more research is being performed and more is being understood about its material properties and behavior. When steel fibers are added to high strength concrete, the raise in fiber volumetric ratio results in a raise in the compressive strength of the concrete and a considerable amount of raise in the tensile strength of the fiber reinforced specimen is observed in split cylinder tests.

Properties of Concrete Improved By Steel Fibers

- Flexural Strength**:** Flexural bending strength can be raised of up to 3 times more compared to conventional concrete.
- Fatigue Resistance**:** Almost 3/2 times rise in fatigue strength.
- Impact Resistance**:** better resistance to damage in case of a heavy impact.
- Permeability**:** The material is less porous
- Abrasion Resistance**:** More effective composition against abrasion and spelling.
- Shrinkage**:** Shrinkage cracks can be eliminated.
- Corrosion**:** Corrosion may influence the material but it will be limited in certain areas

Advantages of Steel Fibers

- More ductile concrete with a high load bearing capacity-resulting in thinner slabs with equal or better performance than their mesh counter parts
- Efficiency crack control -3,200 fibers on average per Kg
- Durability –steel fibers slabs reinforce the structure through of the concrete
- Quick and Easy application – steel fibers can be added at the concrete plants or at the job site directly.
- Efficiency & Cost effective –on average a draw mix slab will cost between 10-15% less than an equivalent mesh slabs.

Workability

We know that it is usually incorrect to add water to concrete for workability. The main trouble with workability of steel fiber reinforced concrete is in getting proper distribution of the fibers so that they don't ball up. This complexity is frequently overcome by slow, continuous and identical feeding of the fibers into the wet or dry mix by means of vibratory feeders. Occasionally the fibers are accepted through screens as they are introduced. Correct feeding can practically eliminate the problem of balling. On the other hand, addition of water to get better workability can reduce the flexural strength considerably; a critical matter when one considers that one of the main reasons for using steel fibers is to improve the flexural strength. In such cases use of appropriate admixture possibly would advance the workability to firm extent and may not to the scope that you need. The workability can be finding by using slump test.

Factors Controlling SFRC

- Aspect ratio (l/d)
- Volume fraction(V_f)
- Fiber reinforcing index, RI=l/d x V_f
- Critical length (l_{min})
- Balling of fibers
- Good mix design: more matrix, small aggregate, workable

PROPERTIES OF MATERIALS

CEMENT

The cement used in this experimental work is 53 grade normal Portland cement confirming to IS: 12269-1987 was used in present study.

Table. 1: Properties of cement

Properties	Obtained
Specific gravity	3.15
Initial setting time	70 min
Final setting time	180 min
Consistency	32%

FINE AGGREGATE

Locally available sand passed through 4.75mm IS sieved. Natural sand as per IS: 383-1987 was used.

Table. 2: properties of fine aggregate

Properties	Obtained
Specific gravity	2.67
Fineness modulus	20562
Bulk density	1094 to 1162 kg/m^3
Water absorption	1.5%
Grading	II

COARSE AGGREGATE

Crushed aggregate available from local sources conforming to IS: 383-1987

Table 3: properties of coarse aggregate

Properties	Obtained
Specific gravity	2.83
Aggregate impact value	14%
Aggregate crushing value	18%
Water absorption	1.85%

SILICA FUME

Silica fume is a waste by-product of the production of silicon and silicon alloys. Silica fume is available in different forms, of which the most commonly used is in a dense form. Silica fume used was conforming to ASTM C (1240-2000)

Table 4: properties of silica fume

Property	Value
Colour	Dark to light gray
Bulk density	450-650 g/cm^3
Specific gravity	2.22
Moisture content	1%
Sio_2	92%

FLY ASH

Fly ash is a byproduct of the combustion of pulverized coal in thermal power plants. A dust-collection system removes the fly ash, as a fine particulate residue, from combustion gases before they are discharged into the atmosphere. Fly-ash particles are typically spherical, ranging in diameter from <1 µm up to 150 µm.

WATER

According to ACI water used for preparing concrete should be of potable quality. In this investigation normal tap water, which is fit for drinking, has been used in preparing all concrete mixes and curative.

SUPER PLASTICIZERS

Plasticizers help us to raise the workability of concrete without addition of extra quantity of water. It means that we can use less water without reducing the workability at the same cement content. This is added to avoid formation of flakes, due to less quantity of water. Use of plasticizers is economical as the cost incurred on them is less than the cost of cement saved. Use of super plasticizers becomes essential for designing mix to achieve HPC and also for the preparation of fiber reinforced concrete to raise workability. Super plasticizer used in this study was Glenium B-233.

STEEL FIBER

For improving the mechanical bond between the fiber and matrix, indented, crimped, machined and hook ended fibers are normally produced. Fibers made from mild steel drawn wire conforming to IS: 280-1976 with the diameter of wire 0.5 mm hasbeenused

Table 5: properties of steel fibers

Fiber properties	Steel fibers
Length (mm)	35 mm
Shape	Hooked End
Size / Diameter (mm)	0.5 mm
Aspect Ratio	60
Density (kg / m3)	7850
Young's Modulus (GPa)	210
Tensile strength (MPa)	**532**

DETAILS OF MIXES

Concrete mix design in this experiment was designed as per the guidelines specified in by IS 10262-1982 and ACI committee. All the samples were prepared based on the design trail mix of M40 grade of concrete was used in the present investigation. In this the mineral admixtures were used to substitute cement by various percentages of cement weight and the percentage of aggregates was kept constant for all mixes.

Casting of Concrete Cubes and Cylinders

Cement Concrete of grade M40 incorporated with the substitutement of mineral admixtures by 5% to 20% by weight of cement was used for preparation of concrete specimens. Cubes with dimension of 150mm × 150mm × 150mm was used for Compression test. All these specimens were casted in cast iron moulds confirming to relevant codes of Indian standards. Prior to casting of specimen, moulds were cleaned, lubricated with oil and all the bolts are fastened tightly so that there is no leakages in the mould.

Curative of the Specimen

The curative was done by immersing concrete specimens in a tank containing water. This method of curative is called as water curative by immersion. The concrete specimens were cured for specified number of days (7, 28 and 45 days) in water at 34± 6^0C and later specimens are taken out of water for testing.

TEST AND RESULTS

RESULTS OF NORMAL CONSISTENCY TEST

Normal consistency of cement with replacement of fly ash

The variation of normal consistency of cement paste with addition of fly ash is shown in the table 6. The normal consistency test shows a very slight increase with the partial replacement of cement by fly ash at different dosages of 5, 10, 15, and 20 % in ordinary Portland cement which are 2% respectively.

Table 6: Variation of Normal consistency with replacement of fly ash

S.NO	Details of Material	Normal Consistency (%)
1	100% cement + 0% FA	32
2	95% cement +5% FA	34
3	90% cement +10% FA	34
4	85% cement +15% FA	34
5	80% cement +20% FA	34

Normal consistency of cement with replacement of silica fume

The variation of normal consistency of cement paste with addition of silica fume is shown in the table 7**.** The normal consistency test shows a very slight increase with the partial replacement of cement by silica fume at different dosages of 5, 10, 15, and 20 % in ordinary Portland cement which are 2% and 4% respectively.

Table 7: Variation of Normal consistency with replacement of silica fume

S.NO	Details of Material	Normal Consistency (%)
1	100% cement + 0% SF	32
2	95% cement +5% SF	34
3	90% cement +10% SF	34
4	85% cement +15% SF	36
5	80% cement +20% SF	36

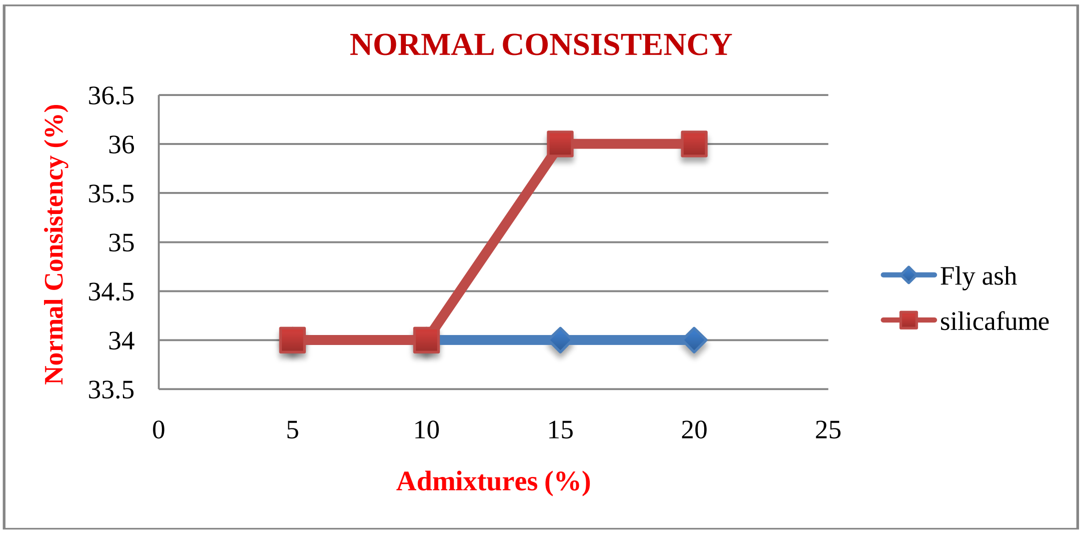

Figure 1: Effect on Normal Consistency for replacement of Cement with different admixtures

From figure 1 it can be seen that the percentage of water required for producing a cement paste of Standard Consistency is increasing with the increase in the amount of admixtures, when used as a partial replacement of cement. The Standard Consistency of normal cement is 32%. The Consistency value increases up to 38% at a replacement percentage of 20 with respect to the Consistency value of normal cement paste.

RESULTS OF INITIAL AND FINAL SETTING TIME

nitial and final Setting time of cement with replacement of fly ash

The variations in the initial and final setting times of cement with addition of fly ash. From table 8 it is observed that both the initial and final setting times got retarded and accelerated by replacement of fly ash in the ordinary Portland cement.

Table 8: Initial and Final setting time values cement with replacement of fly ash

S.NO	Details of Material	Initial Setting Time (minutes)	Final Setting Time (minutes
1	100% cement + 0% FA	45	300
2	95% cement +5% FA	50	300
3	90% cement +10% FA	60	290
4	85% cement +15% FA	70	280
5	80% cement +20% FA	70	260

Initial and final Setting time of cement with replacement of silica fume

The variations in the initial and final setting times of cement with addition of silica fume. From table 9 it is observed that both the initial and final setting times got retarded and accelerated by replacement of silica fume in the ordinary Portland cement.

Table 9: Initial and Final setting time values cement with replacement of silica fume

S.NO	Details of Material	Initial Setting Time (minutes)	Final Setting Time (minutes
1	100% cement + 0% SF	45	300
2	95% cement +5% SF	45	340
3	90% cement +10% SF	45	340
4	85% cement +15% SF	50	330
5	80% cement +20% SF	50	310

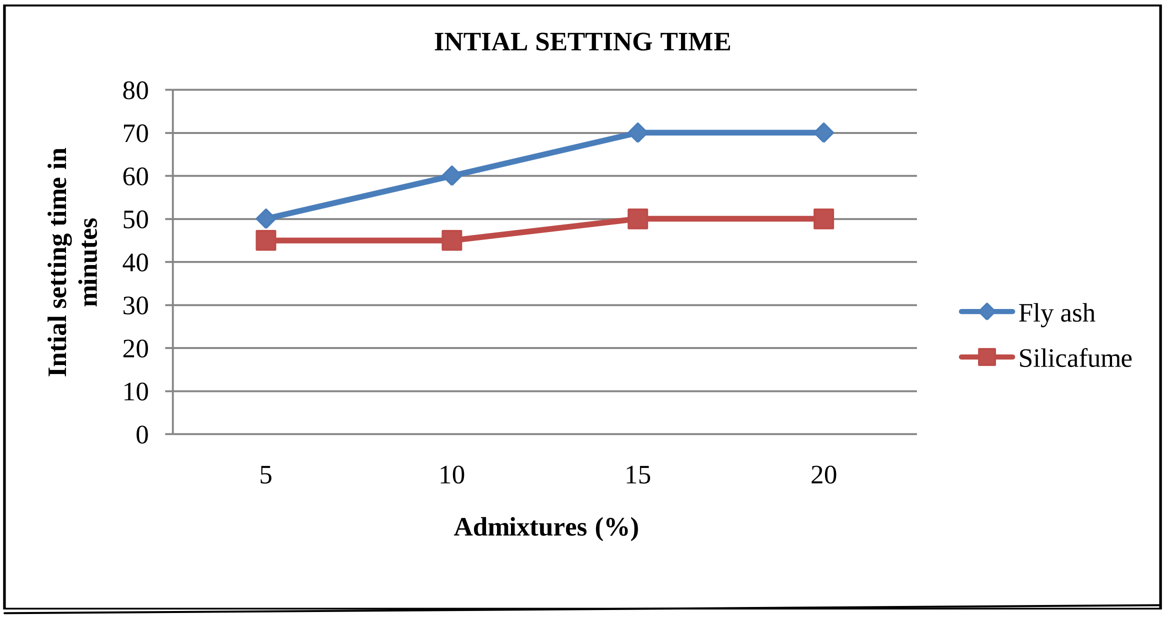

Figure 2: Effect on initial setting time for replacement of cement with different Admixtures

From above results it can be known that the initial setting time of normal cement paste is 45 minutes. From figure 2 the initial setting time was found to increase as the replacement percentage increases after the replacement of 5%. As per the Indian standards, the initial setting time should not be less than 30 minutes. Here all the replacement percentages satisfy this requirement**.**

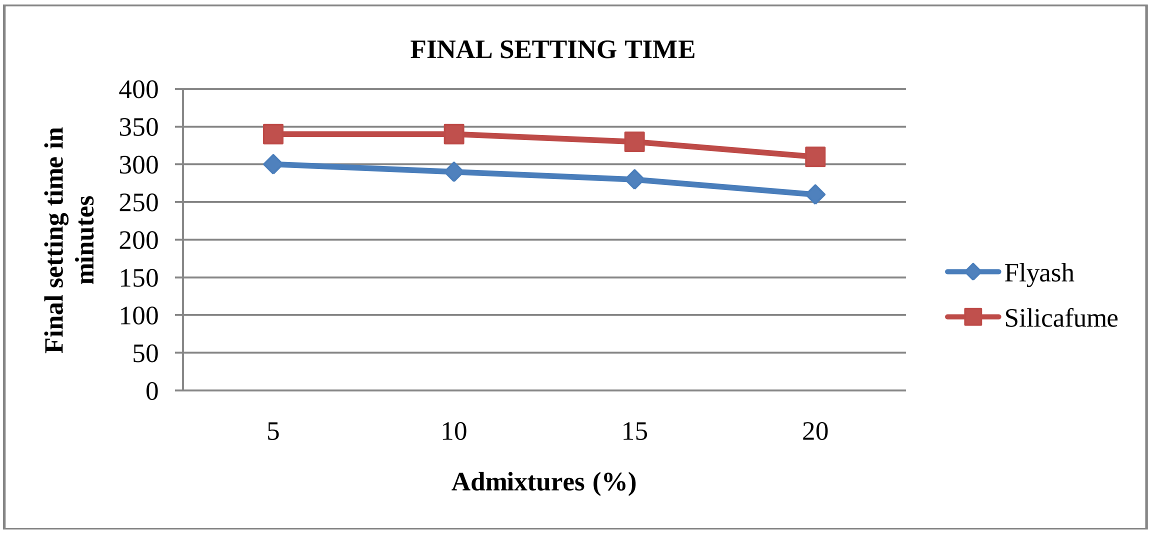

Figure 3: Effect on final setting time for replacement of cement with different admixtures

From above results it can be known that the final setting time of normal cement paste is 300 minutes. From figure 3 the final setting time was found to decrease as the replacement percentage increases after the replacement of 5%, as per the Indian standards, the final setting time should not be more than 600 minutes. Here all the replacement percentages satisfy this requirement.

SOUNDNESS TEST

The expansion of cement specimen was less than 10 mm specified by IS 4031(Part 3)-1988. This confirmed that the cement is a good additive material. Table 5.5 shows the values for soundness of 100% OPC.

Table 10: Soundness of Ordinary Portland cement

Test for Physical Requirement	O.P.C 53 Grade	IS 4031-1988
Lechatlier Method(mm)	1	<10

Soundness of cement with replacement of fly ash

The Le-Chatelier soundness tests were performed on the paste to assess the possibility of deleterious expansion due to the hydration of uncombined calcium oxide and/or magnesium oxide. No evidence of significant possible late expansion was found. The mortar soundness (expansion) for fly ash composite cement indicates shrinkage increase. Increase in soundness with addition of fly ash can be explained by the relative increase in volume of reaction products.

Table 11: Soundness of cement with replacement of fly ash

S.NO	Details of Material	Expansion in mm
1	95% cement +5% FA	1
2	90% cement +10% FA	1.5
3	85% cement +15% FA	1.7
4	80% cement +20% FA	2

Soundness of cement with replacement of silica fume

The Le Chatelier soundness tests were performed on the paste to assess the possibility of deleterious expansion due to the hydration of uncombined calcium oxide and/or magnesium oxide. No evidence of significant possible late expansion was found. The mortar soundness (expansion) for silica fume composite cement indicates shrinkage increase. Increase in soundness with addition of silica fume can be explained by the relative increase in volume of reaction products.

Table 12: Soundness of cement with replacement of silica fume

S.NO	Details of Material	Expansion in mm
1	95% cement +5% SF	1
2	90% cement +10% SF	1.5
3	85% cement +15% SF	1.7
4	80% cement +20% SF	2

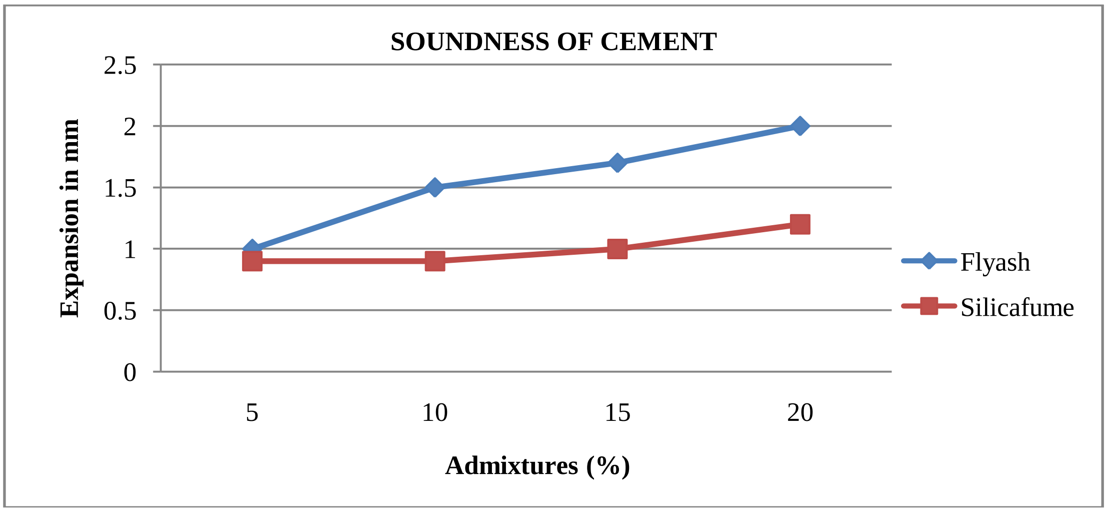

Figure 4: Soundness of Cement with replacement of different admixtures

As per IS 4031(Part 3)-1988 the expansion of cement specimen was specified by less than 10 mm. From figure 4 the soundness of cement was found to increase as the replacement percentage increases after the replacement of 5% to 20%. As per the Indian standards, here all the replacement percentages satisfy this requirement.

FRESH CONCRETE TEST RESULTS

The properties of fresh concrete can be evaluated by slump cone test & compaction factor test with w/c ratio 0.4. The results of properties are given in table 13.

Table 13: Result of slump, compaction factor and density of fresh concrete

S.No.	Mix type (SF %,SF&FA%)	Slump value(mm)	compaction factor
01	MS0(0.0%,0.0%&0.0%)	72	0.952
02	MS1(0.5%,5%&5%)	20	0.820
03	MS2(0.5%,10%&10%)	35	0.810
04	MS3(0.5%,15%&15%)	48	0.902
05	MS4(1.0%,5%&5%)	15	0.801
06	MS5(1.0%,10%&10%)	16	0.786
07	MS6(1.0%,15%&15%)	31	0.802
08	MS7(1.5%,5%&5%)	12	0.740
09	MS8(1.5%,10%&10%)	13	0.792
10	MS9(1.5%,15%&15%)	15	0.810

HARDENED CONCRETE STRENGTH RESULTS

Result of compressive strength for M40 grade on concrete on cube. The specimens are separated by steel fibers, silica fume & fly ash with varying percentage. The table no.14 shows result of compressive strength at 7, 28 & 45 days.

COMPRESSIVE STRENGTH

The test results of compressive strength of M40 grade concrete with various proportions of fly ash, silica fume and steel fibers is shown in Table 14. The variation of compressive strength of M40 grade concrete with different percentages of fly ash and varying percentages of silica fume is shown in Figure 5.

The cube compressive strength indicates the average of three test results. It can be observed that the compressive strength of concrete prepared using fly ash and silica fume exhibits more strength than the control concrete.

Table 14: Compressive strength at 7,28& 45 days

Mix. No.	Steel fibers%	Silica fume%	Fly ash%	Compressive strength(N/mm^2)		
				7 days	28 days	45 days
MS0	0.0%	00%	00%	33.320	48.328	48.328
MS1	0.5%	5%	5%	38.120	41.510	52.476
MS2	0.5%	10%	10%	30.128	37.435	44.954
MS3	0.5%	15%	15%	28.320	30.788	34.578
MS4	1.0%	5%	5%	39.182	44.938	58.120
MS5	1.0%	10%	10%	32.148	42.120	49.320
MS6	1.0%	15%	15%	34.540	39.435	46.542
MS7	1.5%	5%	5%	41.620	46.125	63.140
MS8	1.5%	10%	10%	31.492	43.986	55.130
MS9	1.5%	15%	15%	32.148	42.126	47.160

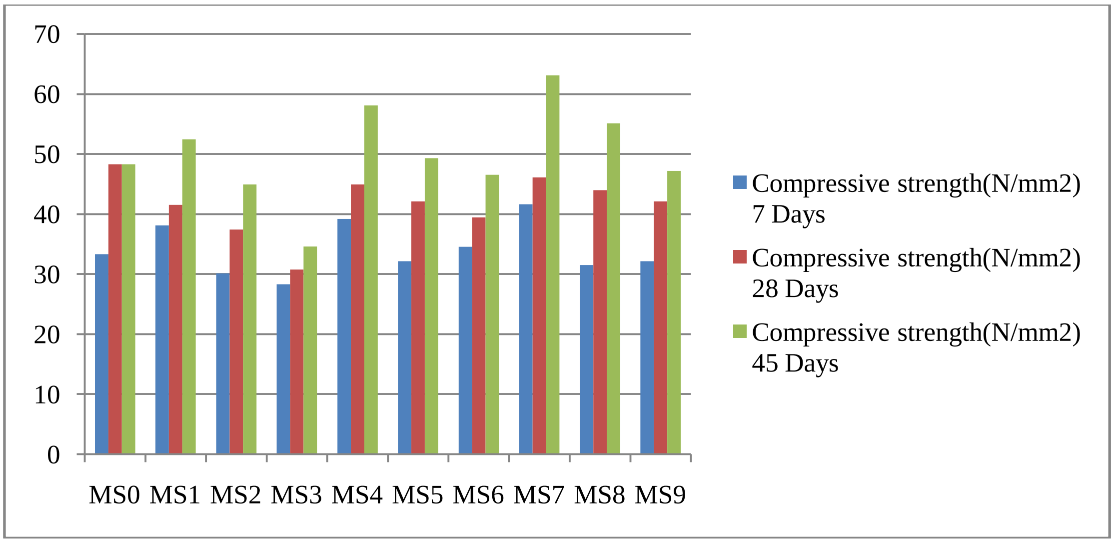

Fig..5 Type of mix vs. compressive strength (N/mm^2) at 7, 28& 45 days

SPLIT TENSILE STRENGTH

The test results of split tensile strength of M40 grade concrete with various proportions of fly ash, steel fibers and silica fume is shown in Table15 The variation of split tensile strength of M40 grade concrete with different percentages of fly ash and varying percentages of silica fume is shown in Figure.6

Table 15: Split tensile strength at 7 & 28 days

Mix. No.	Steel fibers%	Silica fume%	Fly ash%	Split tensile strength(N/mm^2)	
				7 days	28 days
MS0	0.0%	00%	00%	3.30	3.8
MS1	0.5%	5%	5%	2.84	3.2
MS2	0.5%	10%	10%	3.05	3.85

MS3	0.5%	15%	15%	3.57	3.75
MS4	1.0%	5%	5%	3.32	4.12
MS5	1.0%	10%	10%	2.64	4.26
MS6	1.0%	15%	15%	2.93	4.67
MS7	1.5%	5%	5%	3.12	3.89
MS8	1.5%	10%	10%	2.96	4.45
MS9	1.5%	15%	15%	3.28	3.98

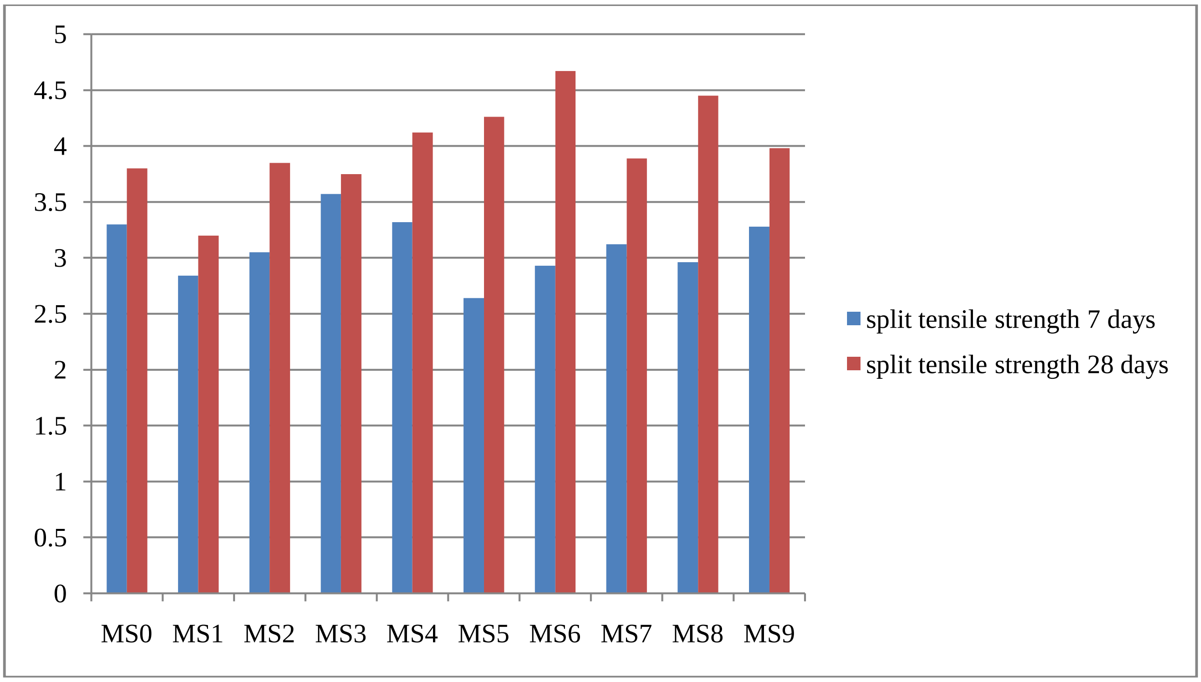

Fig. 6 Type of mix vs.split tensile strength (N/mm^2) at 7& 28 days

FLEXURAL STRENGTH

The test results of flexural strength of M40 grade concrete with various proportions of fly ash, silica fume and steel fibers is shown in Table16. The variation of flexural strength of M40 grade concrete with different percentages of fly ash and varying percentages of silica fume is shown in Figure7.

Table 16: Flexural strength (N/mm^2) for 7 days.

Mix. no	Steel fibers %	Silica fume%	Fly ash%	Flexural strength(N/mm^2) 7 Days
MS1	0.5%	5%	5%	4.712
MS2	0.5%	10%	10%	4.120
MS3	0.5%	15%	15%	4.182
MS4	1.0%	5%	5%	5.182
MS5	1.0%	10%	10%	4.320
MS6	1.0%	15%	15%	4.896
MS7	1.5%	5%	5%	6.182
MS8	1.5%	10%	10%	5.920
MS9	1.5%	15%	15%	4.520

Fig.7: Type of mix vs Flexural strength (N/mm^2) at 7 days

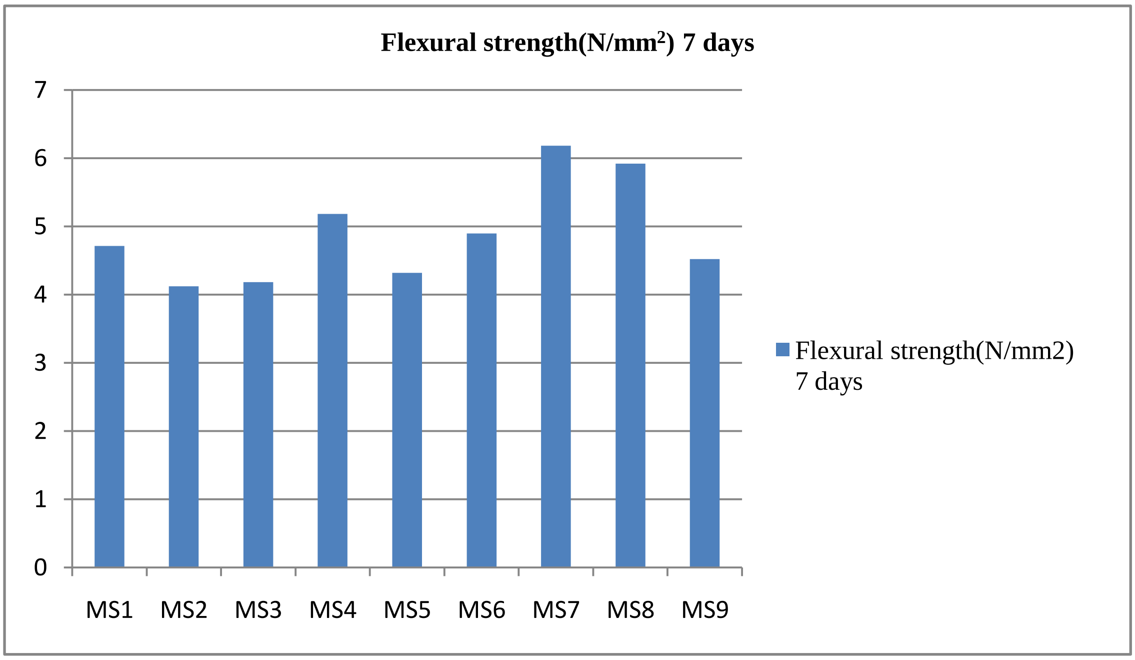

Fig.7: Type of mix vs Flexural strength (N/mm2) at 7 days

CONCLUSIONS

The study on the effect of steel fibers with Fly Ash and silica fume can still be a promising work as there is always a need to overcome the problem of weakness of concrete. The following conclusions could be drawn from the present research.

1. Marginal raise is observed in the workability as percentage of Fly Ash and silica fume rises.
2. Density of concrete is more as the proportion of steel Fiber raises.
3. Compaction factor is raises as the Steel Fiber proportion decreases.
4. Higher percentage of Steel Fibers slump was down.
5. Water falling agent is required for workable mix as percentage of Steel Fiber raises.
6. Stiffness of specimens is raised because of Steel Fibers, Fly Ash and silica fume.
7. The strength of specimen is about 82% at 28th day and 95 to 100% at 45 days, because of steel fibers, Fly Ash and silica fume.
8. Specimen of MS1, MS4&MS7 having high Flexural strength as well as Compressive strength.
9.Specimen number MS4 having high split tensile strength compare to normal concrete.
10. For small quantity of Fly Ash and silica fume (10%&20%) Compressive Strength is more for 1.0% & 1.5% Steel Fibers.

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